California Current Monitoring Using The NPS Ocean Acoustic Observatory

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LONG-TERM GOAL

The long-term research goals are:

1. To achieve a permanent, real-time capability in monitoring the meso- to large-scale temperature variability off Central California using decommissioned SOSUS arrays as receivers in a tomographic system.

2. To understand the physics and variability of long-range, low-frequency sound traveling initially downslope from a seamount, through the California Current Front over deep water, and then upslope through inshore waters. Important questions to be addressed are: What role does each of the three geographical regimes play in the composition of the received signal?

OBJECTIVES

The effort reported here is part of a multi-institutional project titled "Ocean Acoustic Observatory Federation" sponsored by the National Ocean Partnership Program. Scripps Institution of Oceanography is the lead partner of the project. The objectives of the Naval Postgraduate School (NPS) component are to operate and maintain the NPS Ocean Acoustic Observatory (OAO) and to develop a real-time ocean acoustic tomography network to monitor the California Current System.

APPROACH

The approach is to implement a tomographic observing system consisting of the decommissioned Pt Sur, San Nicholas and Centerville SOSUS arrays, and an autonomous low-frequency sound source. While the Pt Sur array is operated by the NPS OAO, the San Nicholas and Centerville arrays are maintained by the Applied Physics Laboratory of the University of Washington (UW/APL). The autonomous sound source is an HLF-5 supplied by the Scripps Institution of Oceanography. The HLF-5 is capable of transmitting tomography signals over one mega-meters and still retain a high enough signal-to-noise ratio (SNR) after pulse compression and coherent averaging (Munk et al., 1995). Our experimental plan is to place the sound source on Hoke Seamount, approximately 600 km offshore, for a period of one year. This placement should form three reliable transmission paths that traverse different parts of the California Current System. Hoke Seamount has a minimum depth of 768 m. This depth is very close to the deep sound channel axis and thus the acoustic propagation condition should be good.

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Since we have real-time access to the Pt Sur data, the initial focus of our data analysis will on the Hoke-to-Pt Sur acoustic path. Sound propagation modeling will be performed to predict the arrival structure of the observed tomographic signals. The stability and variability of the observed acoustic arrival pattern as influenced by ocean processes will be examined through model-data comparison. Inversions of the acoustic arrival data for temperature will be performed. The quality of these tomographically derived ocean variable estimates will be assessed using resolution and variance analysis.

Once we have developed a good handle on the forward and inverse problems, our plan is to derive real-time, routine products, particularly for the Hoke Seamount-to-Pt Sur transmission path. These real-time products will include spatially averaged temperature, coarse-resolution maps of the temperature along the path, and annual and interannual oscillations of the lowest baroclinic modes if annual redeployment of the source is possible. Off real time, the data from the San Nicholas and Centerville stations will also be utilized in the tomographic analysis.

WORK COMPLETED

1. On the operation/maintenance of the Pt Sur Observatory, we have (i) developed and installed a multi-channel, full-array data archival system, (ii) upgraded the telephone cable at Pt Sur, and (iii) re-surveyed the locations of the hydrophone elements of the underwater array.

2. The implementation of the ocean-margin tomography observational network to study the California Current involved the deployment of an HLF-5 sound source on top of the Hoke Seamount, 600 km off shore. This sound source was successfully deployed in early May, 1999. A short mooring was used to minimize source motion and to place the source close to the axis of the deep sound channel.

3. Required by the forward propagation modeling and inverse initialization of the tomographic method, meso-scale resolving CTD/XBT surveys and continuous depth echo-sounding measurements along the geodesic path was also carried out during the deployment cruise. Using the measured sound speed profiles and bathymetry, acoustic modeling of the basic arrival structure has begun.

RESULTS

The HLF-5 source was programmed to transmit both tomographic M-sequence signals and RAFOS signals. The source has a carrier frequency of 250 Hz and an output level of 192 dB re 1 μPa. The transmission schedule was designed to consist of an initial 24 tomographic transmissions on the hour at one hour intervals to allow for an assessment of proper source operation during the cruise, followed by one-year, low-duty-cycle transmissions for the main experiment. The main schedule consists of tomographic transmissions every fourth day and RAFOS signal transmissions every day. During the days of tomographic transmissions, signals are sent at 4-hr intervals to allow for resolving tidal variability.

During the cruise, UW/APL and NPS reported that the tomographic signals were heard at various SOSUS stations along the West Coast. In particular, a pre-processed, omni-directional signal-to-noise ratio (SNR) exceeding 4 dB at the decommissioned Point Sur array off Central California was measured. Although the Pt Sur array is approximately 600 km from the source, a high omni-directional

SNR of 43 dB in the processed data is attained. UW/APL reported that the signals were also heard by the Barbers Point array off Hawaii, approximately 2000 km from the Hoke Seamount. This was a nice surprise.

Forward propagation modeling for the signal transmissions from Hoke Seamount to Pt Sur is in progress. Our propagation modeling uses a range-dependent ray-theory model with input sound speed field and bathymetry derived from hydrographic and echo sounding measurements obtained from the source deployment cruise. While the hydrographic data is displayed in Figure 1, the pulse-compressed signals received at Pt Sur in Yearday 149 of 1999 along with the modeled arrival structure are displayed in Figure 2. Note that the source transmitted every four hours resulting in six realizations of the acoustic arrival structure over the day. Four groups of arrivals (A,B,C and D) are consistently observed in all of the transmissions. The fine structure within each group, however, are observed to vary from time to time. Model results show that each of the four groups are composed of overlapping individual ray arrivals and that the variation of the fine structure within each group are due to phase interference. The temporal variability of the ray-group travel times are directly related to range-averaged temperature changes. In an effort to increase spatial resolution, an inversion scheme that can account for the phase interference of the multipaths are being formulated at present.

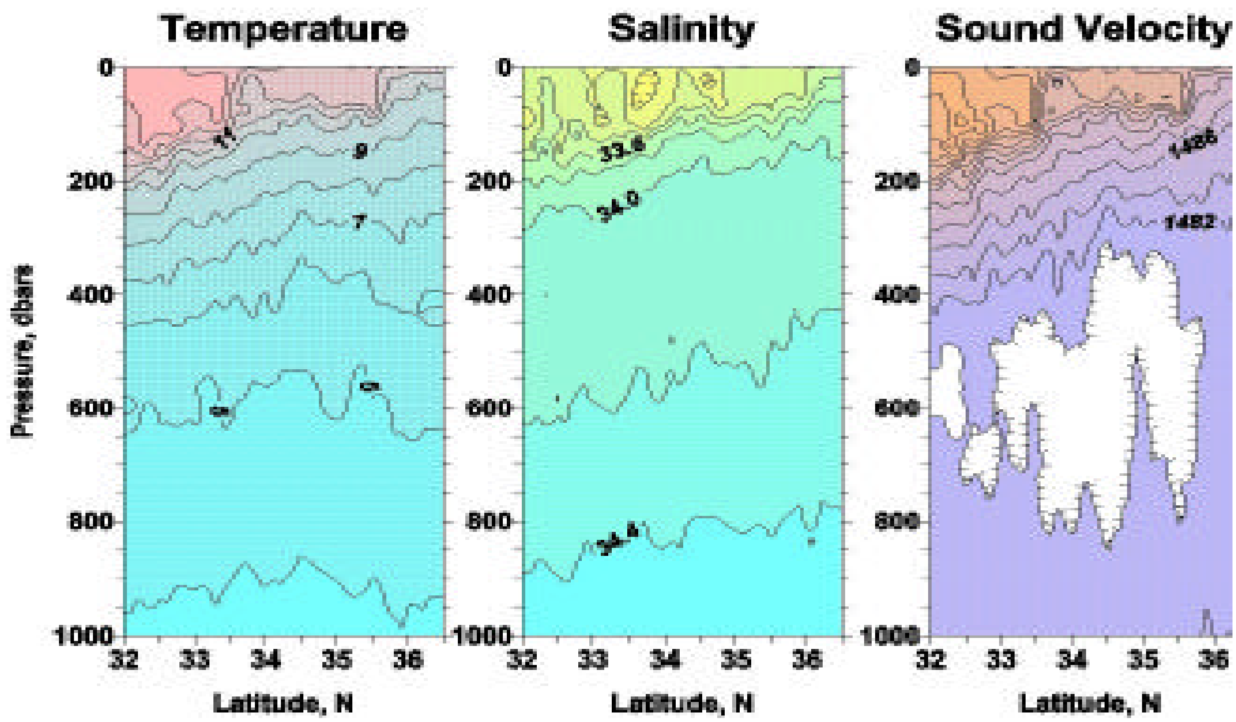

Figure 1. Surveyed temperature, salinity and sound speed sections between Hoke Seamount (~32° 06' N, 126° 54' W) and Pt Sur (~36° 18' N, 122° 23' W). The hydrographic data shows that isovels and isohalines above 400 m shoaled to the north. Below 400 m, the 6-7°C isotherms were shallowest at about 34.5°N, and deepened northward and was associated with poleward flow at intermediate depths. In the upper 100 m, two strong fronts were observed at 33.5°N and 36°N; the location of the former also coincided with the lens of low salinity surface water (S<33) associated with the core of southward flowing Subarctic water in the California Current. The deep sound channel had speeds less than 1480 m/s and was centered between 450 and 600 dbars.

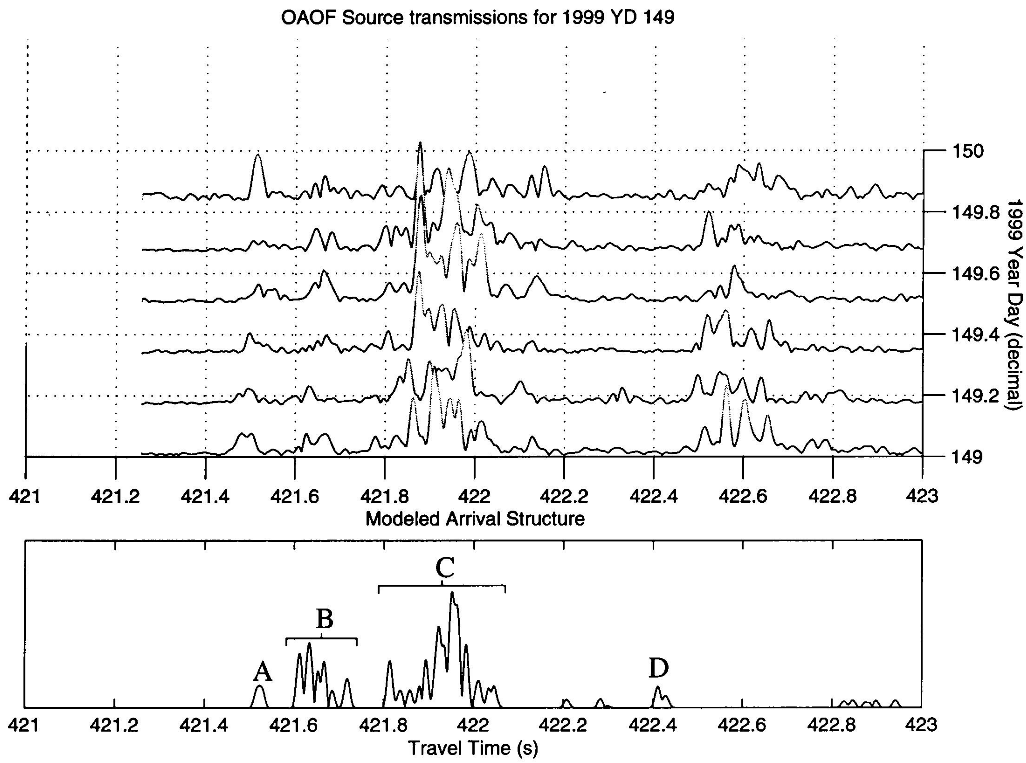

Figure 2. Modeled acoustic arrival structure (lower panel) of the transmitted signal from Hoke Seamount and a comparison to the observed arrival structure (upper panel).

IMPACT/APPLICATIONS

The combined acoustic and oceanographic data set will allow for an in-depth understanding of the physics and variability of the sound field in a complex downslope-upslope propagation geometry, as well as for validating tomography as a useful tool for regional, ocean-margin monitoring.

TRANSITIONS

The real-time ocean maps and acoustic measurements generated by this project can be used to validate and calibrate ocean forecast model for the region. The data can also be assimilated into regional ocean models to enhance ocean prediction accuracy.

RELATED PROJECT

This project strongly compliments another NOPP project called Innovative Coastal Observing Network (ICON). ICON studies the ocean processes in the Monterey Bay area which is influenced by the California Current.

REFERENCES

Munk, W., P. Worcester, and C. Wunsch, “Ocean Acoustic Tomography,” Cambridge University Press, 1995.

PUBLICATIONS

Rocheleau, M., “Light Bulb Survey Procedure and Sensitivity Study for Estimating Element Locations of the NPS OAO Bottom Lying Horizontal Array,” NPS MS Thesis, June 1999.

Collins, C., C.-S. Chiu and P. Worcester, “California Current Tomography Cruise Report,” prepared for the Office of Naval Research and the National Ocean Partnership Program, August 1999.